

# In-Situ Arsenic Removal During Groundwater Recharge Through Unsaturated Alluvium:

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# Arsenic Background

- Naturally occurring in Rocks/Soil
- Carcinogen from Chronic exposure
  - cancers (bladder, skin, lung), hypertension, diabetes, children's IQ
- 50 ppb → 10 ppb (Jan 2006)
- ~40% (18/45) wells have exceeded MCL



# Current Operation

- Blending High As wells w/ Low As wells
  - Needed for ~15 wells consistently above MCL
- Some wells partially abandoned
- Some inactive or destroyed
- Not a long term solution
- Depleting shallow aquifer



# Arsenic Treatment?

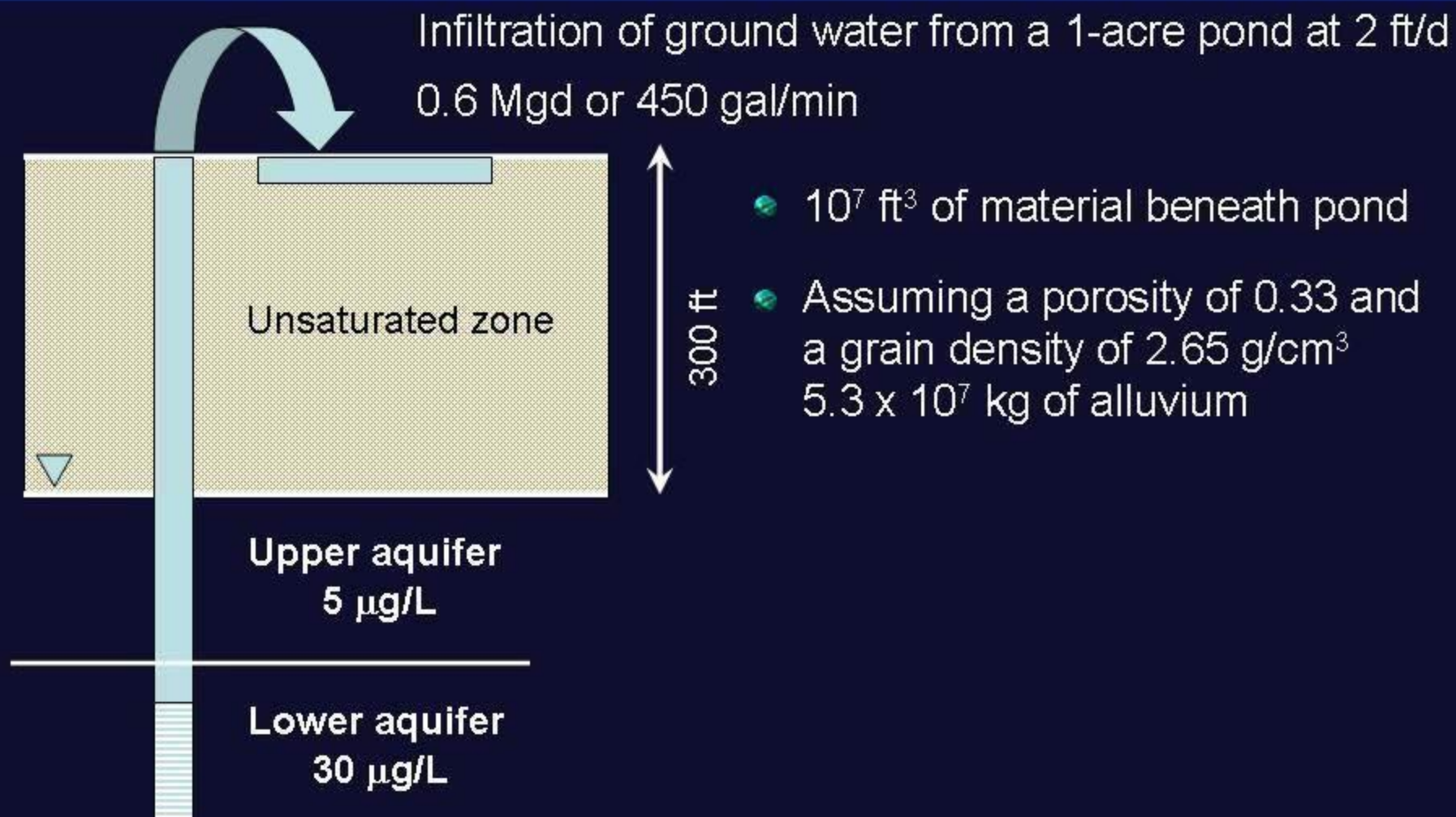
- EPA treatments high cost
- Adsorptive media
- Coagulation/filtration
- Ion Exchange
- \$0.5M for 500 gpm + \$700/AF

# Alternate Option

- USGS Oro Grande findings
- Artificial recharge experiment
- Mojave Desert along Oro Grande Wash near Victorville
- Thick unsaturated zone
- Similar soil properties - oxides

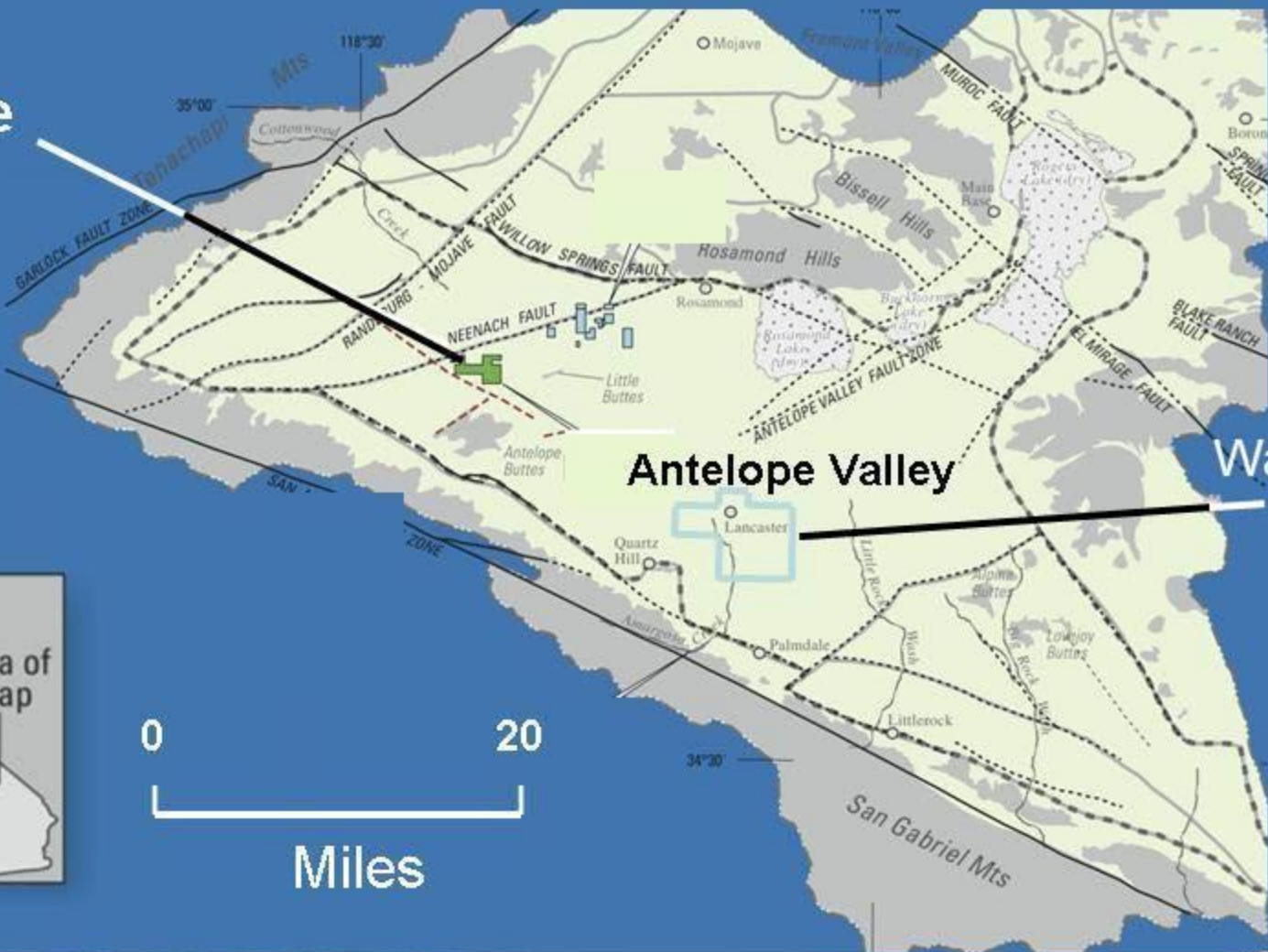


# Proposed *insitu* treatment of arsenic



# Study area location

Arsenic  
Recharge  
pond



Waterworks  
District



0 20  
Miles



# Initial Pond Construction





# Initial Water Application

- Began November 30, 2010





# Berm Failure

- Suspended water application on December 4, 2010

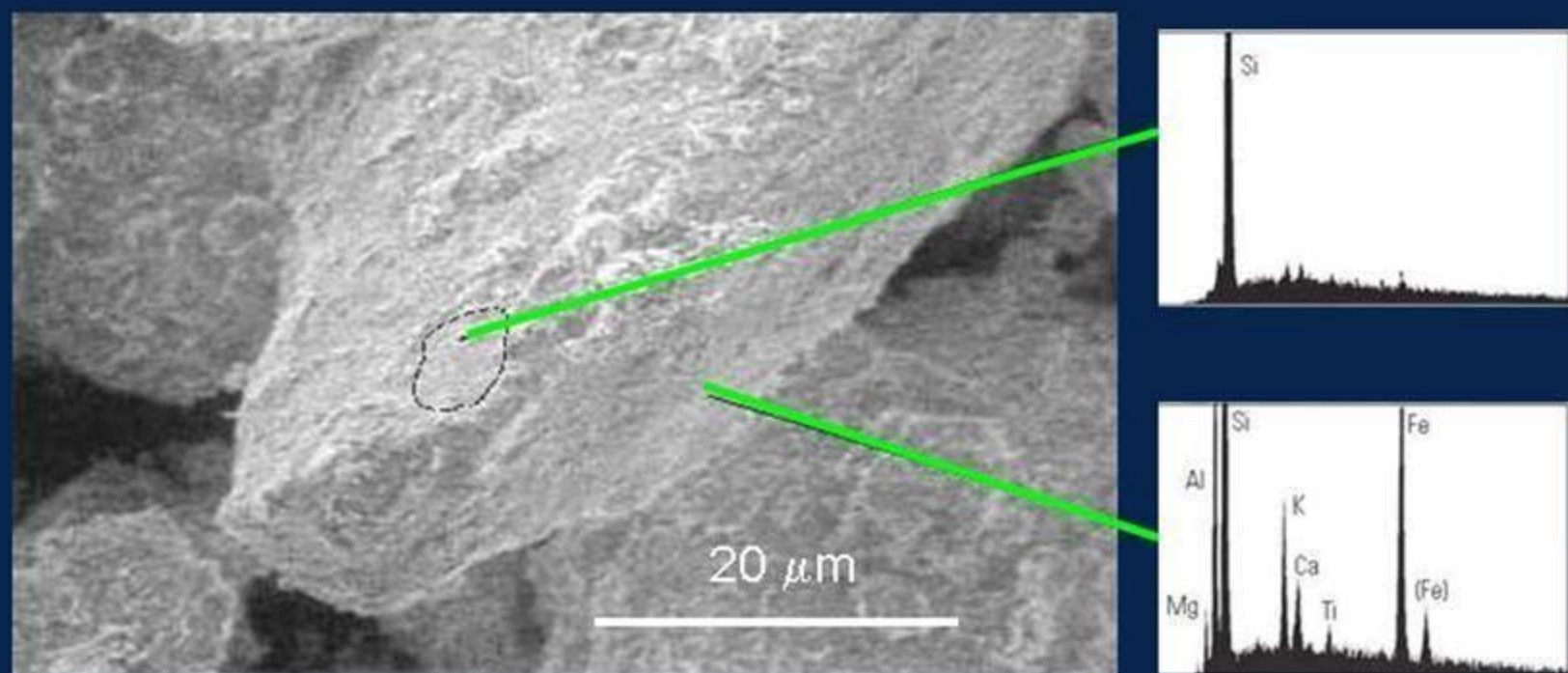


# Below Ground Surface Pond



Resumed water infiltration January 2011

# Why will this approach work



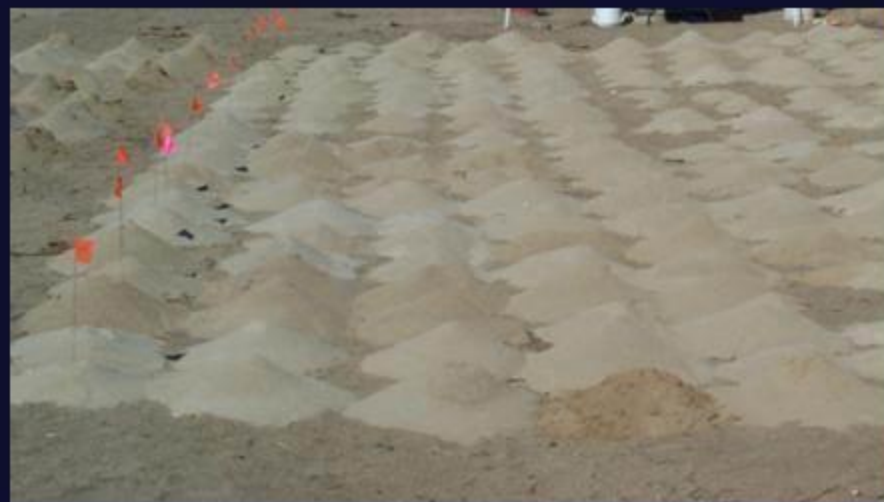
- Abundant alumina, iron, and manganese oxides present as surface coatings on mineral grains
- The same chemistry that forms the basis for absorptive media sold commercially for arsenic removal



# Infiltration, clays, and surface area

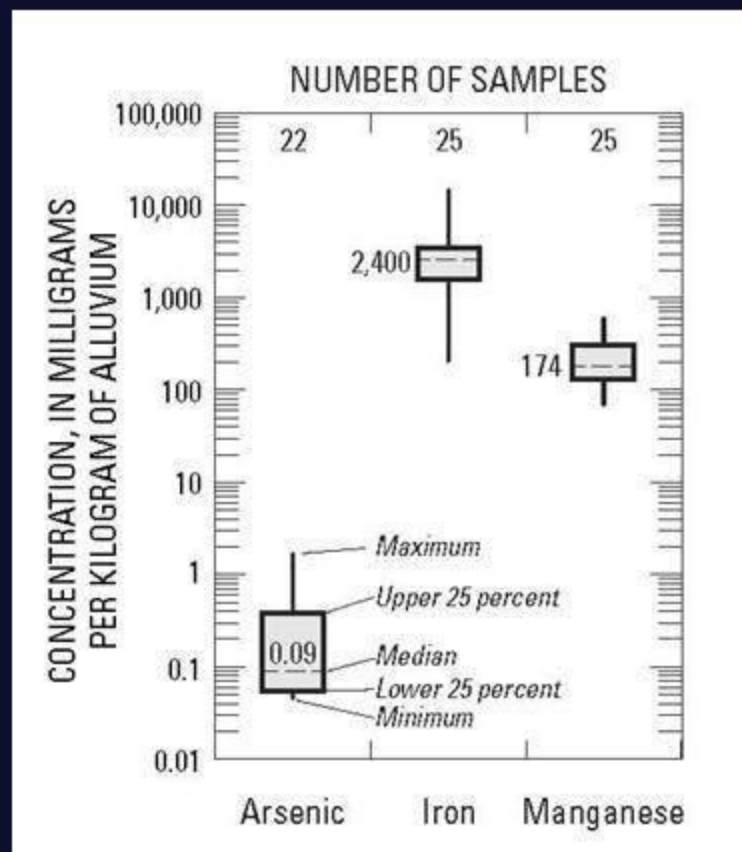


- Extensive paleosol development within the Victorville fan – initial infiltration to the water table required 3 years



- Limited paleosol development in Warren basin at the mouth of Water Canyon – infiltration to the water table occurred in 4 months

# Arsenic concentrations on sorption sites



- The bulk of the alluvial material is Inert silicate minerals
- Granitic alluvium  
0.09 milligrams per kilogram  
After breakthrough  
9.5 milligrams per kilogram
- Spent activated iron media  
5.5 grams per kilograms  
Spent activated alumina media  
4 grams per kilograms



# Drilling

- ODEX drilling technology
- Air is the drilling fluid



USGS drill rig and crew



Sample collection at 1-foot intervals

# Instrumentation and site construction



1. Heat-dissipation probe – to measure matric potential in very dry material
2. Advanced tensiometer – to measure matric potential of wetter material and head in saturated material
3. Suction-cup lysimeter – to collect water from unsaturated material



Road-rated vault awaiting installation of data logger



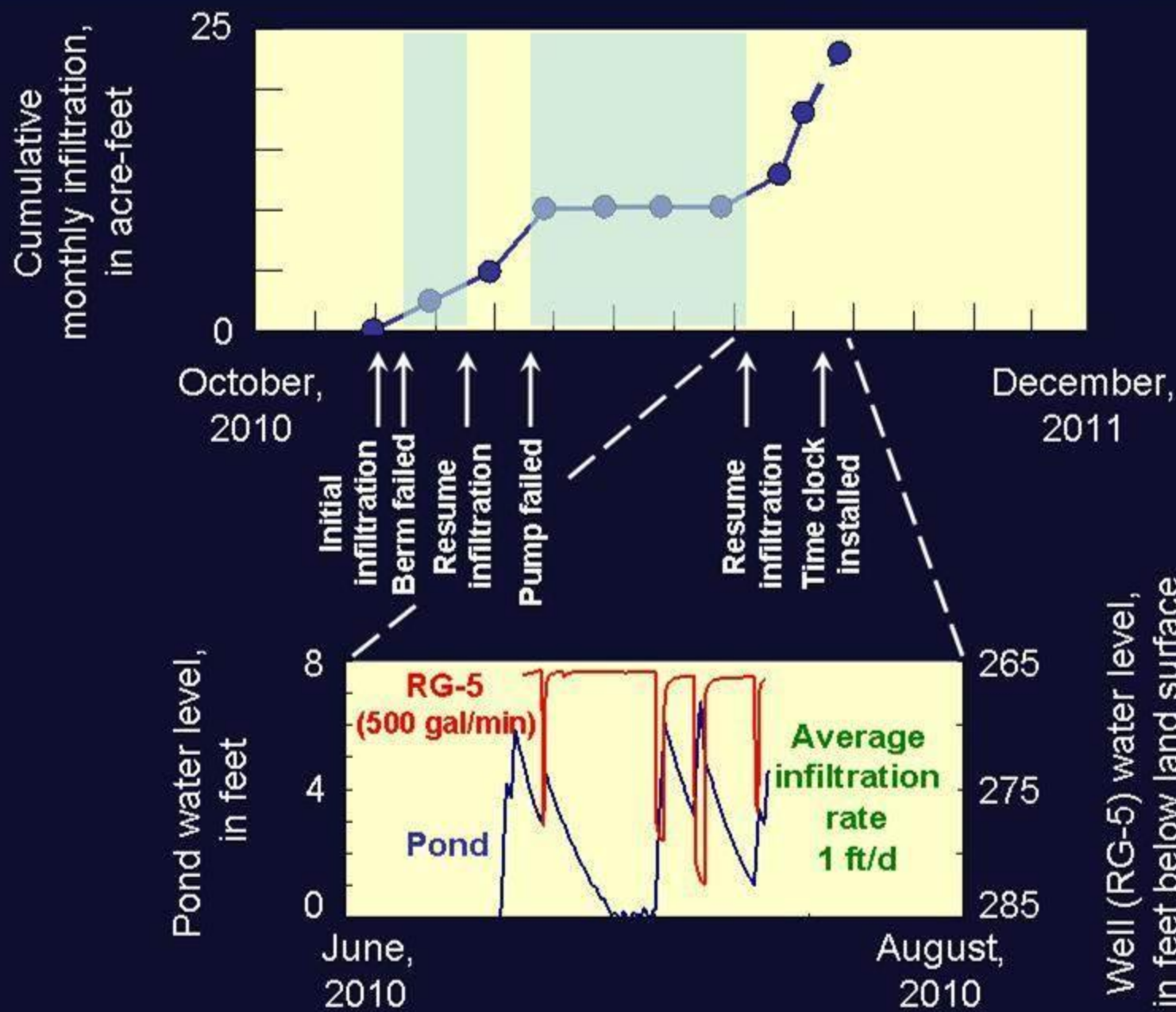
Installation of heat-dissipation probe strapped to advanced tensiometer



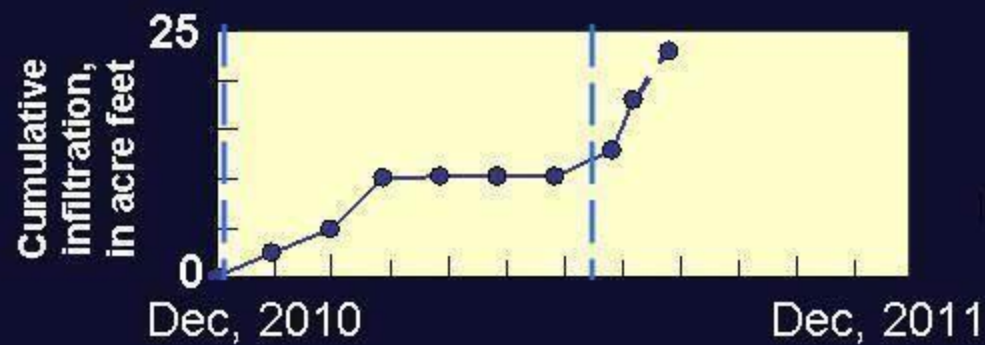
Complex sites may have as many as 17 instruments with cables and tubing connecting instruments to the surface



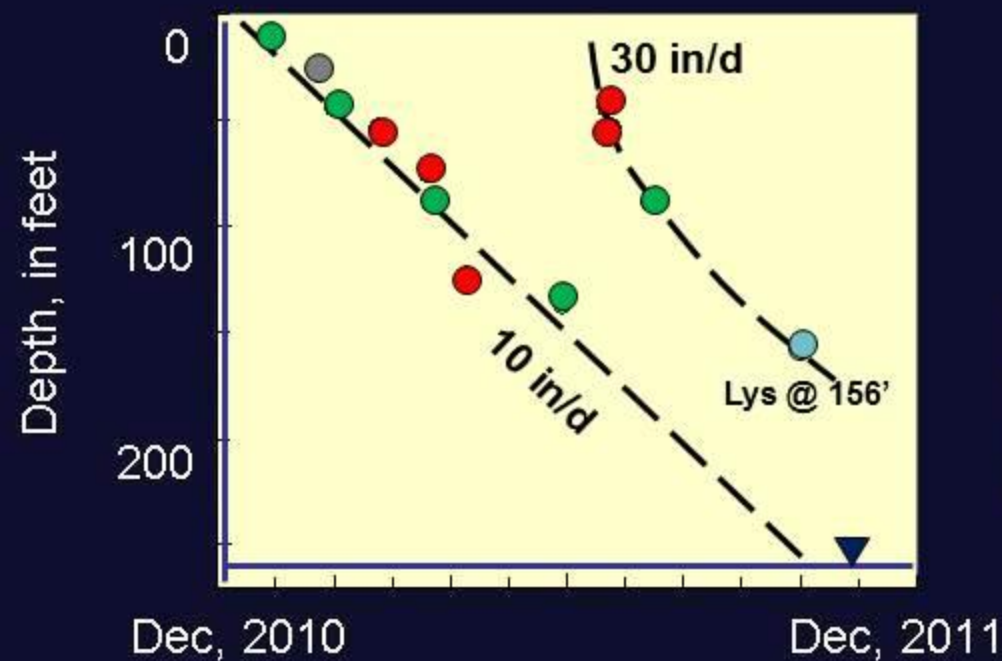
# Pond operation



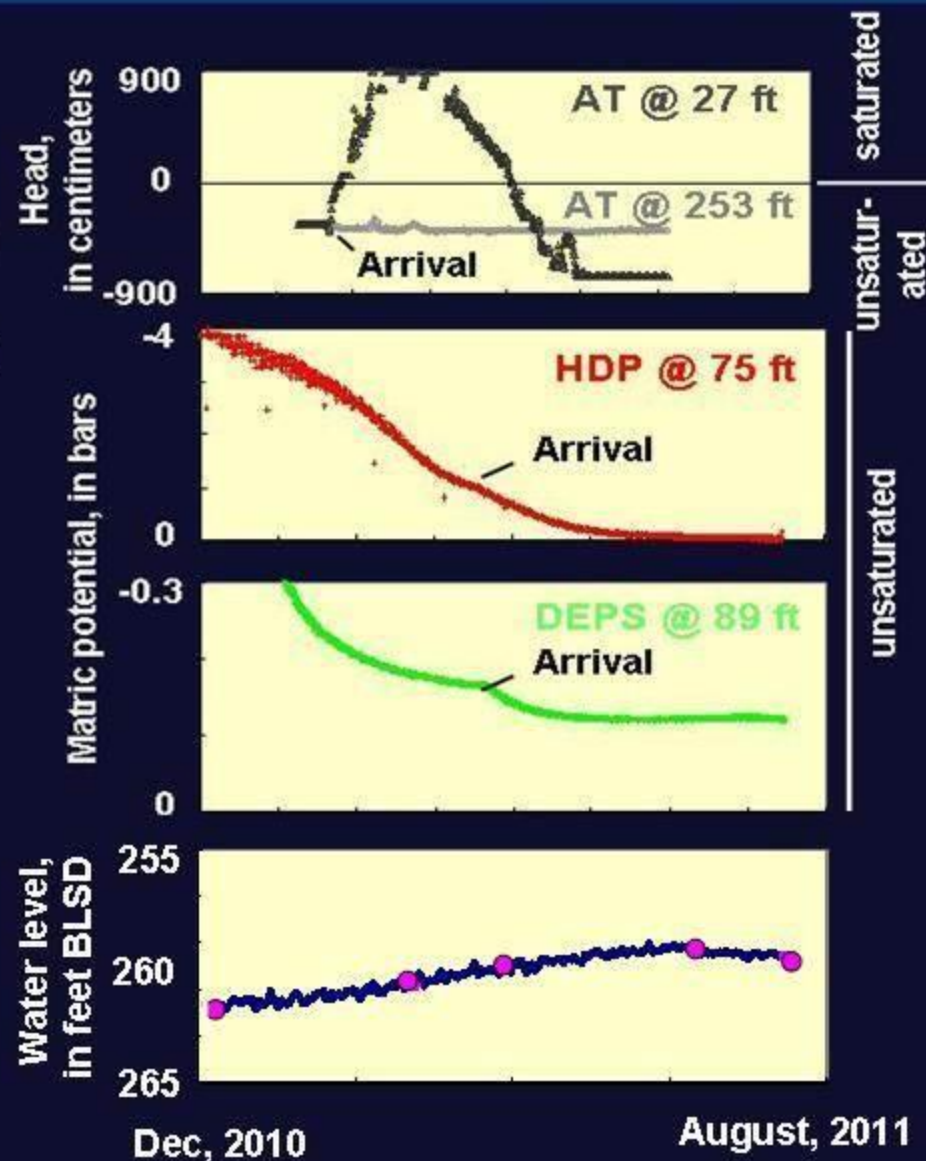
# Downward movement of wetting front, AVUZ-4



Initial application December 1, 2011  
Second application June 16, 2011



● Advanced tensiometers (ATs)

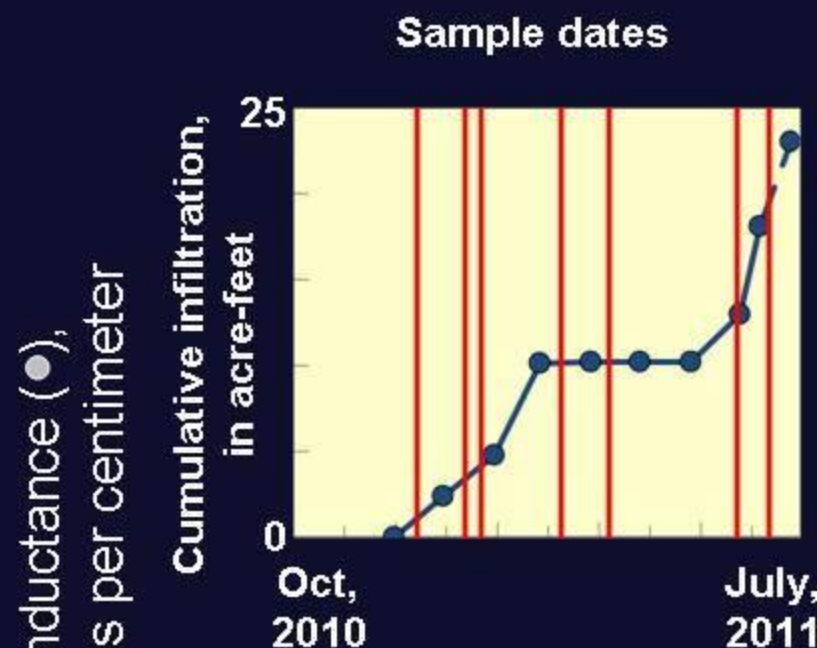
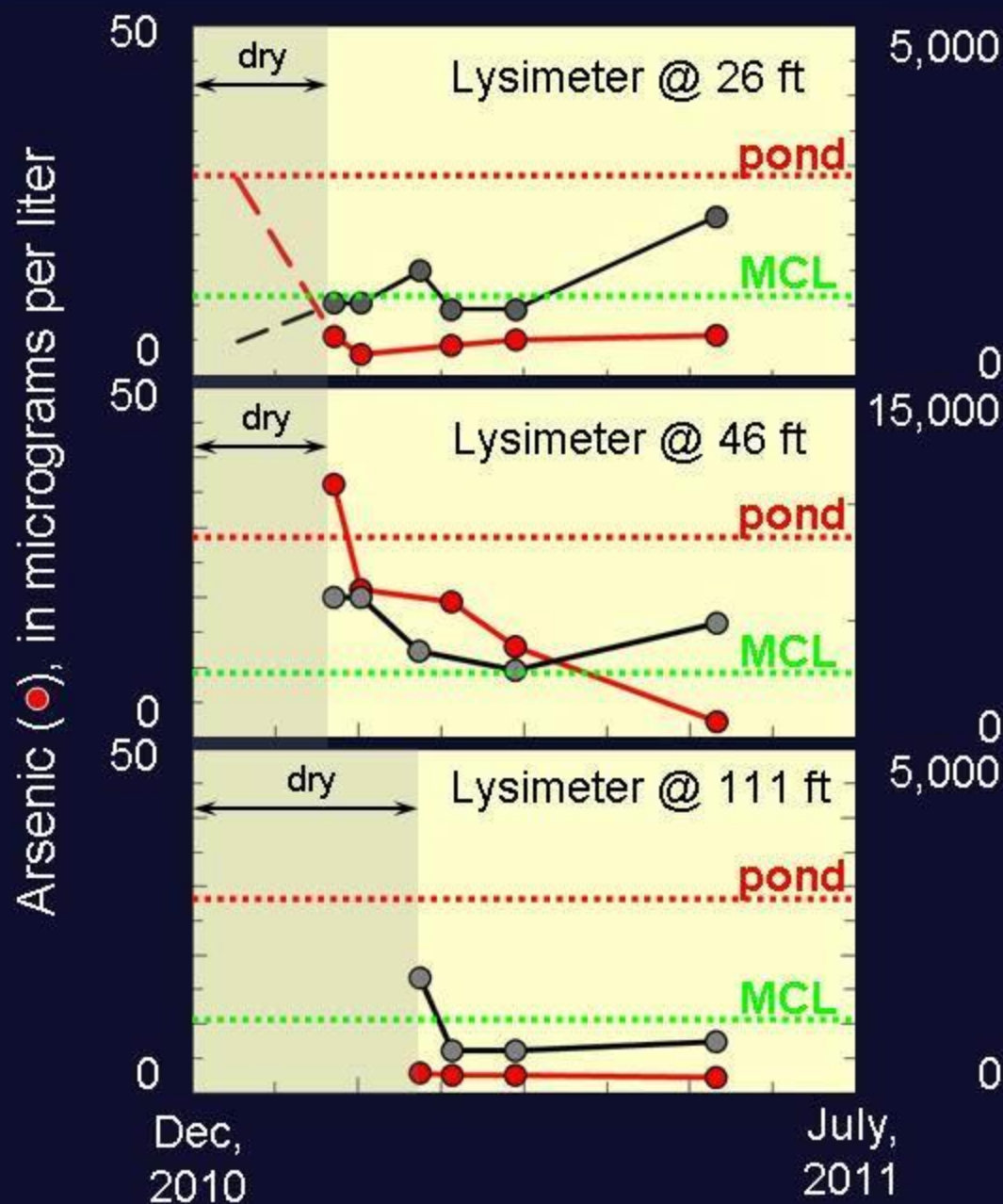


● Heat-dissipation probes (HDPs)

● Dielectric permittivity sensors (DEPSs)

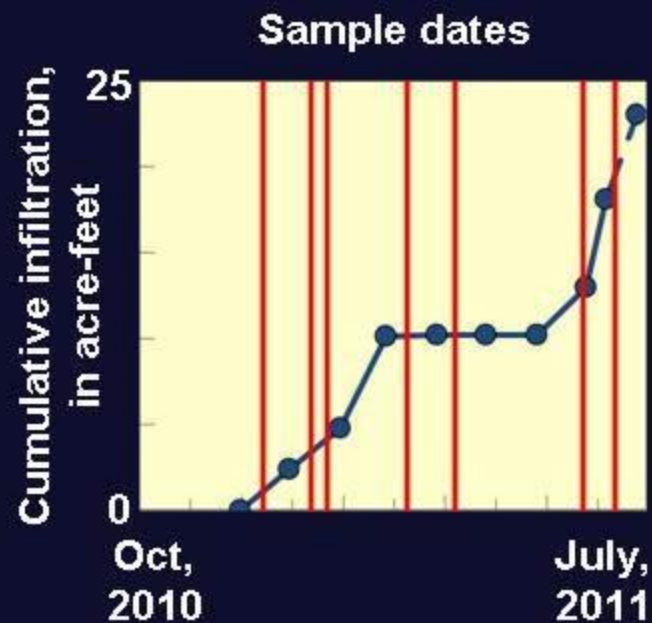
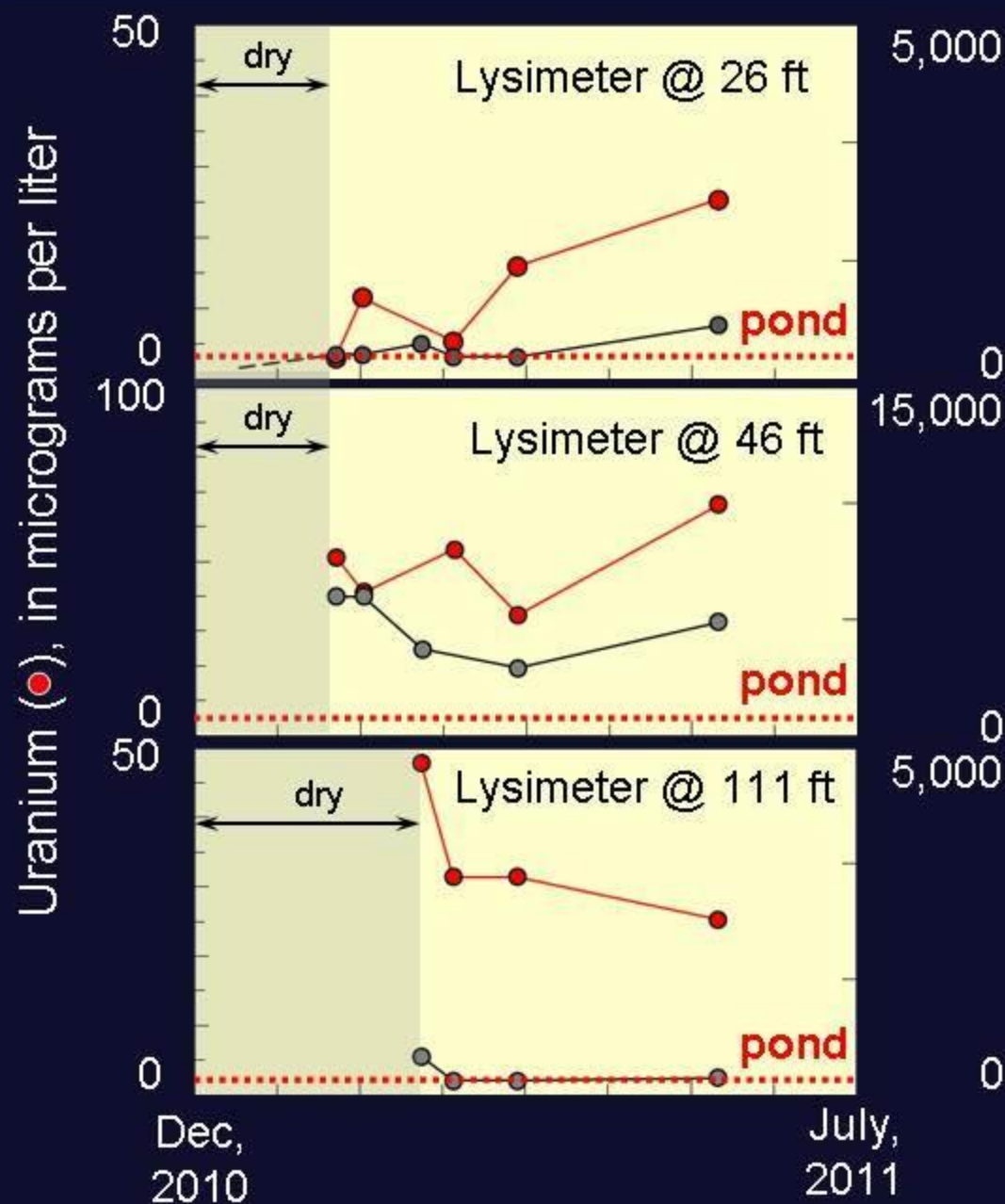


# Arsenic concentrations, AVUZ-4



- Lysimeter @ 154 ft dry
- Lysimeter @ 252 ft has arsenic of about 6 μg/L
- Water-table well has arsenic of about 5 μg/L

# Uranium concentrations, AVUZ-4



- Lysimeter @ 154 ft dry
- Lysimeter @ 252 ft has uranium of about 0.7  $\mu\text{g/L}$
- Water-table well has uranium of about 2.5  $\mu\text{g/L}$



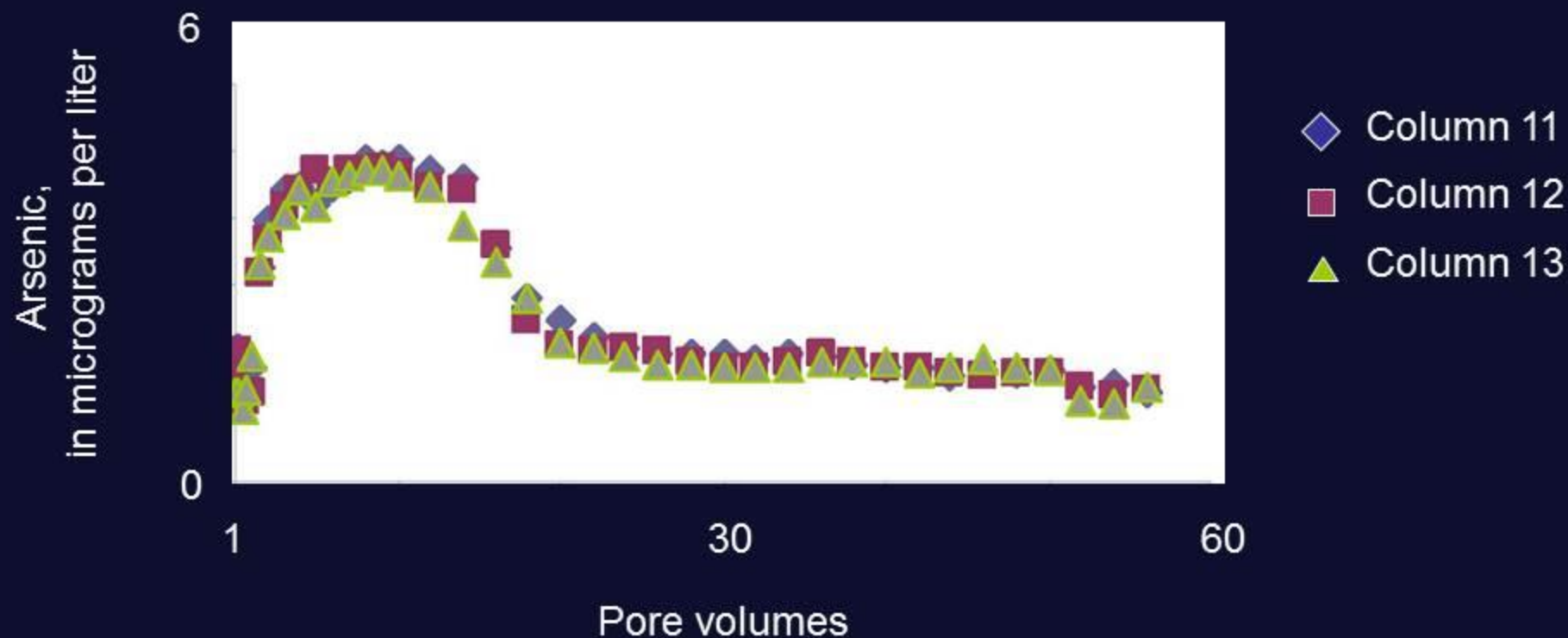
# Column experiments

- Testing materials to minimize sorption
- Range of geologic materials and textures to assess the effect of particle-size and oxide abundance
- Range of pH's to evaluate pH dependence of sorption
- Use of “synthetic water” to control for competition for sorption sites by other oxyanions



# Column experiment results

pH = 8  
arsenic = 300 micrograms per liter



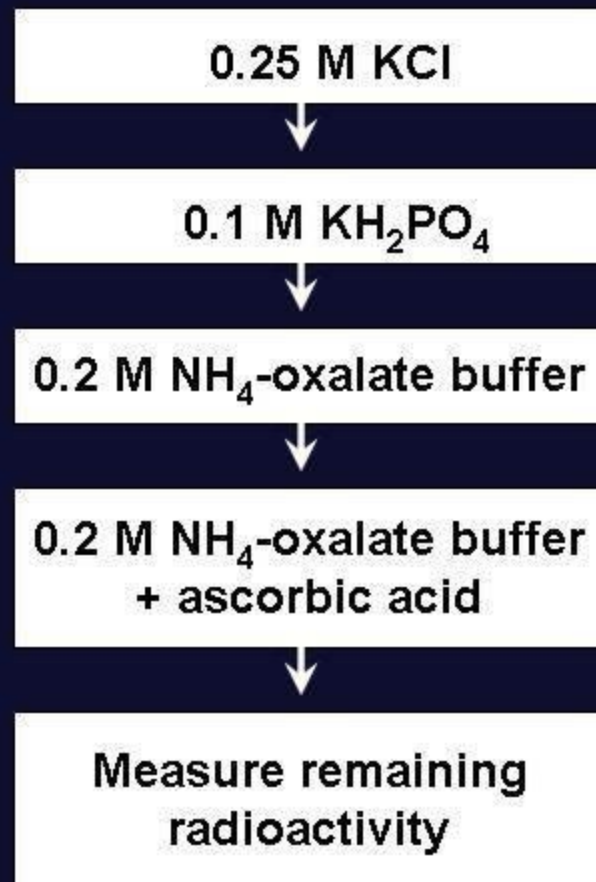


# Radiolabeled Arsenic-73 experiments

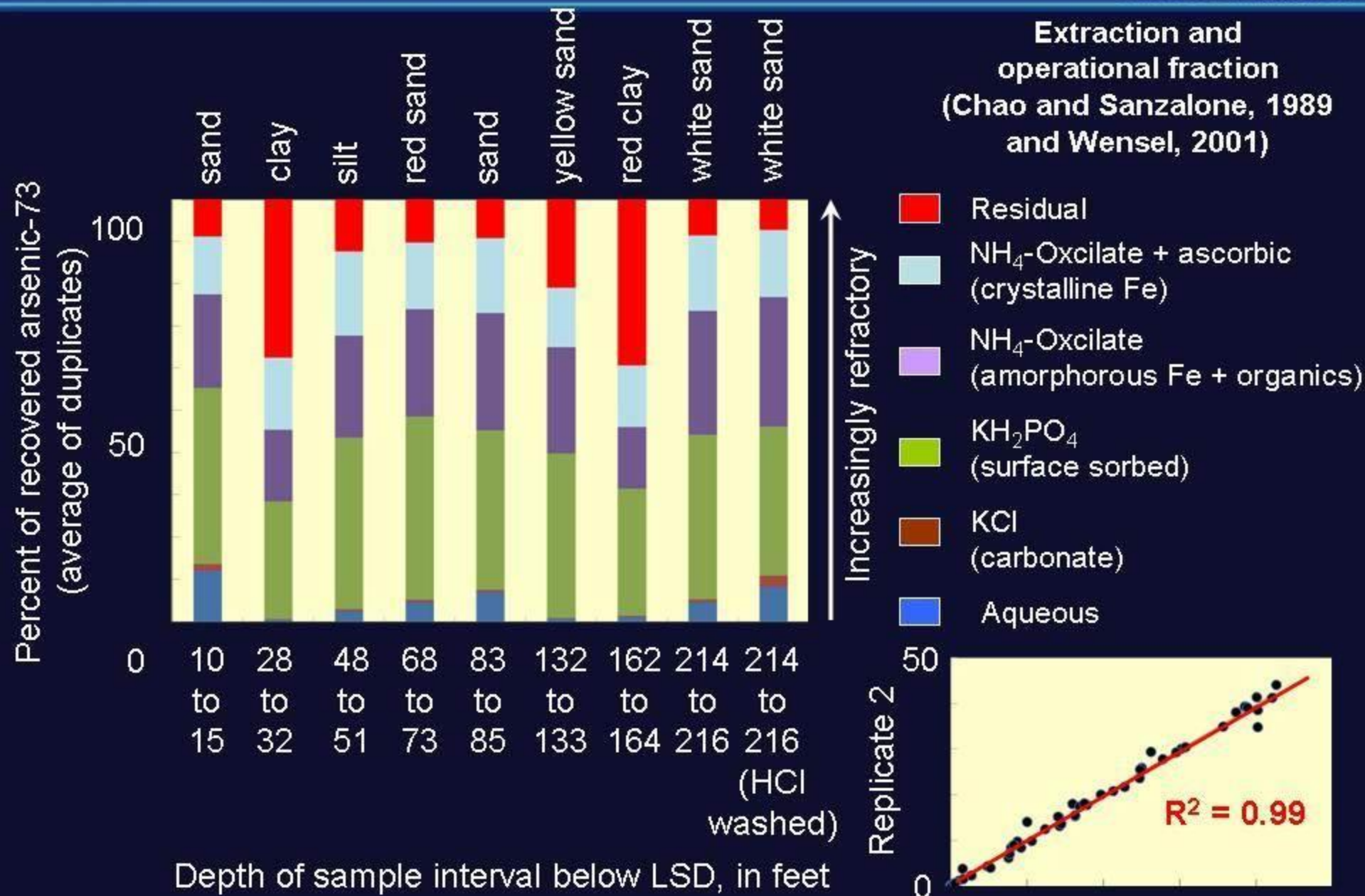
- Samples spiked with As-73 and incubated for up to 1 year
- Replicates periodically harvested and arsenic sequentially extracted
- As-73 mobilized by each extraction step analyzed by gamma spectroscopy



## Sequential Extraction



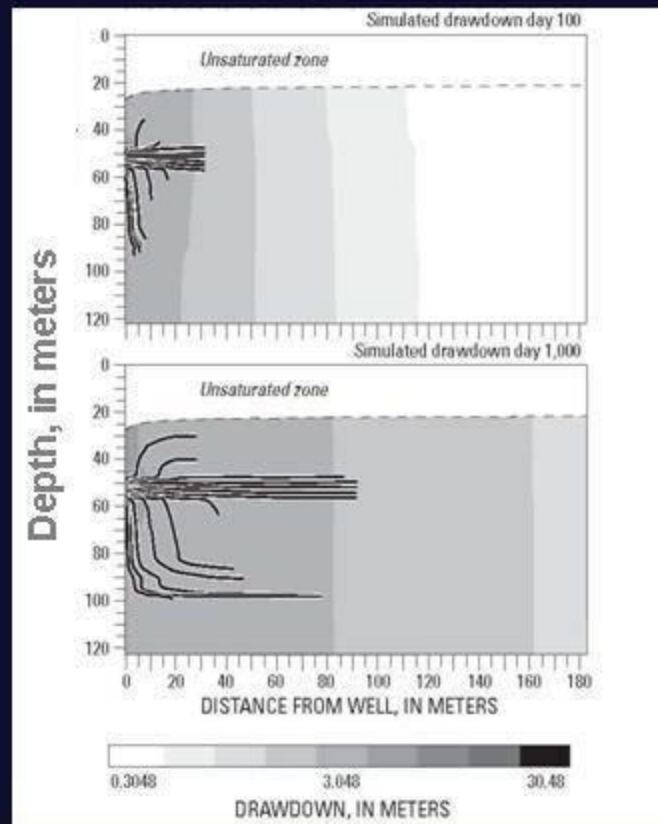
# Arsenic-73 experiment at time = 0





# Benefits

- Pumping from deep aquifer controls pressure induced upward movement of high-arsenic water
- Restores a source of water supply lost as a result of regulatory changes
- Minimal costs and infrastructure without generation and disposal of waste
- Treated arsenic remains *insitu* and never leaves the site



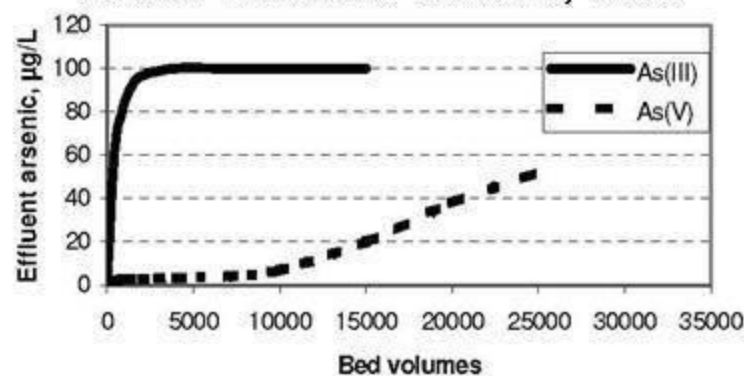
Induced movement of water from deeper aquifers by pumping

# Concerns and limitations

- Arsenic III is less readily sorbed than Arsenic V
- Potential concerns about mobility of trace elements such as chromium and vanadium
- Preferential flow and rapid transport of arsenic to the water table
- Optimize pumping rates and pond size to ensure adequate depressurization of underlying aquifer at minimal cost

*Caution: do not infiltrate water having a high organic carbon load* such as aqueduct water, treated municipal wastewater, or stormflow runoff to ensure maintenance of oxic conditions. Similarly, frequent cleaning of the pond may be required to minimize development of algal mats

Sorption of arsenic on activated alumina  
After Frank and Clifford, 1986





# Questions and answers

*Los Angeles County DPW-Waterworks District gratefully acknowledges that the Water Research Foundation, and Los Angeles County DPW-Waterworks District are co-owners of certain technical information upon which this presentation is based. Los Angeles County DPW-Waterworks District thanks the Water Research Foundation, for their financial, technical, and administrative assistance in funding the project through which this information was developed.*

